Author: **Joseph Rasson** | Department: **Mechanical Engineering** | Date: **18 November, 2002**

Technical Specifications

LHC Cryogenic Distribution Boxes
Fabrication, Assembly, Test, and Shipping

Submitted by: **DFBX Engineering Group**

Author: _____ **LBNL LHC Deputy Project Manager**
Joseph Rasson

Reviewer: _____ **LBNL LHC Lead Cryogenic Engineer**
Jon Zbasnik

Approved by: _____ **LBNL LHC Project Manager**
William Turner

TABLE OF CONTENTS

ATTATCHMENTS:

1 General Information

The US LHC Accelerator Project will provide eight cryogenic distribution boxes (DFBX) to CERN for the Large Hadron Collider in Geneva, Switzerland. These distribution boxes connect the superconducting magnets built by Fermi National Accelerator Laboratory (Fermilab) and Brookhaven National Laboratory (BNL) to the LHC cryogenics, high-current DC power, and instrumentation systems. Lawrence Berkeley National Laboratory (LBNL) is responsible for the design and fabrication of the distribution boxes.

The purpose of this document is to provide the technical specifications by which the DFBX will be fabricated, assembled, tested and shipped to CERN. LBNL will provide specialized components, such as power leads, internal instrumentation, the magnet power bus duct assemblies (MQX1 and MBX1), magnet instrumentation conduits (MQX2 and MBX2), and jacketed beamtubes. A complete list of equipment provided by LBNL to the Subcontractor for assembly into the distribution boxes is given in Attachment 3.

A total of eight distribution boxes will be fabricated. All boxes are of similar design and complexity but vary slightly from each other depending on their location in the LHC ring. Two pairs of boxes are identical to each other other, accounting for six different variants of the design. The major difference is in cases when the boxes are not connected to superconducting magnets on one end resulting in fewer cryogenic pipes. Top-level assembly drawings listed in Table 1 serve to illustrate the configuration of the assembled distribution boxes and indicate the degree of variation in design details and complexity over the six types.

Table 1 and the top-level assembly drawings summarize the design variations among the eight distribution boxes. Each box is located on the left or right side of one of the four crossing “Interaction Regions” (IR) of the LHC (IR1, 2,5, and 8), and is given a unique designation according to its location. Table 1 shows the location, designation and the top-level assembly drawing number for each distribution box. Note that DFBX-G and DFBX-H (IR8) are identical to and follow the same assembly drawings as DFBX-C and DFBX-D (IR2) respectively. The complete list of Bill of Materials (BOM) and drawings is given in Attachments 4 and 5.

The top-level assembly drawings show the general configuration of each box and its internal piping. One end connects to the superconducting quadruple magnet in all 8 cases. The opposite end connects to a superconducting dipole magnet in four of the boxes and a warm dipole in the other four locations. The two jumpers extending from the top of the box connect to the LHC cryogenic transfer line. The jumpers are always pointing away from the center of the ring regardless of location. The assembled distribution boxes include power leads rated at 7.5 kA, utilizing high temperature superconductor (four in each of four of the boxes and six in each of the other four), and four assemblies of

conventional vapor cooled power leads rated at 600 A or 120 A. The power leads extend upwards from the liquid helium vessel in two rows; the HTS leads are always on the side opposite the connection to the cryogenic transfer line. All leads will be purchased separately by LBNL for integration by the fabricator into the distribution boxes.

Table 1. Design summary of eight Dabs.

Location	Designation	Assembly Drawing	Features
IR1 Left	DFBXA	24C351	Cryogenic and electrical services for superconducting quadruple magnet extend from one end. The pipes exiting from this end are the same for DFBXA, DFBXC, DFBXF and DFBXG. There are slight differences in the internal routing of the pipes. The other end has a vacuum beam pipe extending from it and is otherwise sealed. Contains four 7.5 kA high temperature superconducting (HTS) power leads.
IR1 Right	DFBXB	24C350	Cryogenic and electrical services for superconducting quadruple magnet extend from one end. The pipes exiting from this end are the same for DFBXB, DFBXD, DFBXE and DFBXH. There are slight differences in the internal routing of the pipes. The other end has a vacuum beam pipe extending from it and is otherwise sealed. Contains four 7.5 kA high temperature superconducting (HTS) power leads.
IR2 Left	DFBXC	24C352	Cryogenic and electrical services for superconducting quadruple magnet extend from one end. The pipes exiting from this end are the same for DFBXA, DFBXC, DFBXF and DFBXG. There are slight differences in the internal routing of the pipes. The other end has cryogenic and electrical services for a super conducing dipole magnet. Contains six 7.5 kA high temperature superconducting (HTS) power leads. DFBXC is identical to DFBXG.
IR2 Right	DFBXD	24C362	Cryogenic and electrical services for superconducting quadruple magnet extend from one end. The pipes exiting from this end are the same for DFBXB, DFBXD, DFBXE and DFBXH. There are slight differences in the internal routing of the pipes. The other end has cryogenic and electrical services for a super conducing dipole magnet. Contains six 7.5 kA high temperature superconducting (HTS) power leads. DFBXD is identical to DFBXH.
IR5 Left	DFBXE	24C394	Cryogenic and electrical services for superconducting quadruple extend from one end. The pipes exiting from this end are the same for DFBXB, DFBXD, DFBXE and DFBXH. There are slight differences in the internal routing of the pipes. The other end has a vacuum beam pipe extending from it and is otherwise sealed. Contains four 7.5 kA high temperature superconducting (HTS) power leads.
IR5 Right	DFBXF	24C395	Cryogenic and electrical services for superconducting quadruple extend from one end. The pipes exiting from this end are the same for DFBXA, DFBXC, DFBXF and DFBXG. There are slight differences in the internal routing of the pipes. The other end has a vacuum beam pipe extending from it and is otherwise sealed. Contains

			four 7.5 kA high temperature superconducting (HTS) power leads.
IR8 Left	DFBXG	24C352	Identical to DFBXC
IR8 Right	DFBXH	24C362	Identical to DFBXD

2 Applicable Codes and Standards

The following is a list of various codes is to be applied to the design, fabrication, assembly and tests of the cryogenic distribution boxes.

1 ASME - American Society of Mechanical Engineers
- Boiler & Pressure Vessel Code Sec VIII,
- Properties of Material, Design Sec IID
- Process Piping, B31.3
- Refrigeration Piping, B31.5

2 ASME Y14.5M-1994 Dimensioning Tolerance Code

3 ASTM – American Society for Testing Materials
- Material specification for Stainless Steel
- ASTM E-498 Standard Test Methods for Leaks Using the Mass Spectrometer Leak Detector or Residual Gas Analyzer in the Tracer Probe Mode

4. AWS – American Welding Society Section D1.1
- Welding technique, testing, welder qualification and weld rod specification

5 AVS- American Vacuum Society (AVS)
- Vacuum Leak Check Standard. 2.1

6 ISO – International Organization for Standardization
- For metric fasteners, threads, and flange specification

7 NEMA – National Electrical Material Association
- Material specifications

8 LBNL Publication 3000
- LBNL Health and Safety Manual available at the following URL: http://www.lbl.gov/ehs/pub3000/

9 ASA – American Standard Association
- Material, flange, elbow, and reducer specification

10 MIL- SPEC - Military Specification
- Peek Gasket material specifications MIL-P-4681 TYPE I (NATURAL)

11 CDA – Copper Development Association
- Copper material specifications

12. EJMA –Expansion Joint Manufacturers Association
    - Bellow design

3 Fabrication Requirements

3.1 General Requirements:

The cryogenic distribution boxes shall be fabricated and assembled to the dimensions and instructions detailed in the fabrication drawing package. The subcontractor shall develop the fabrication and assembly processes using accepted engineering practices that meet the design intent and offer best value to LBNL

3.2 Piping Assemblies:

3.2.1 Subcontractor shall attach "pressure-tested" labels to pipe ends to identify that the pressure acceptance test is completed.

3.2.2 Subcontractor may substitute fittings for tube bends as needed with LBNL approval.

3.2.3 Subcontractor may consider alternate welding preps with LBNL approval.

3.2.4 Subcontractor may select the type of ends on the flex hoses. In locations where flex hose ends are specified on the LBNL fabrication drawings, the Subcontractor may select alternate ends with LBNL approval.

3.2.5 Subcontractor shall substitute tubes with pipes or vice-versa with LBNL approval as long as the following conditions are met:

3.2.5.1 Tube O.D and I.D exiting the DFBX (interfaces to other equipment) are unchanged from what stated in the fabrication drawings.

3.2.5.2 Minimum flow cross section area is maintained as stated in the fabrication drawings.

3.2.5.3 Wall thickness suitable for pipe pressure rating

3.2.5.4 Minimum clearance between pipe assemblies is greater than 0.5 inch after installation.

3.3 Thermal Shield:

3.3.1 Subcontractor may consider alternate methods to fasten the thermal shield panels to one another as long as good thermal contact is maintained and subject to LBNL approval

3.3.2 Subcontractor may consider alternate method to anchor the trace cooling tubes to the thermal shield subject to LBNL approval as long as allowance for the differential thermal contraction is taken into account and adequate thermal contact is maintained.

3.4 Multi Layer Insulation (MLI):

3.4.1 Multi Layer Insulation (MLI) is specified in LBNL Specification M-990 and is included in Attachment 10

3.4.2 Subcontractor may consider alternate MLI material or alternate method of application subject to LBNL approval.

3.4.3 For safety reasons there shall be a minimum of 10 layers of MLI applied to the liquid helium vessel.

3.5 Helium Vessel:

3.5.1 All welds and weld preps in the helium tank assembly must be made in accordance to the ASME Pressure Vessel Code with the exception of the close out weld of the access panel.

3.5.2 All longitudinal welds in the helium tank except for the tank door welds must be radiographed. The radiographs and their interpretation must be included as part of the traveler as required by the Acceptance Specification No. LBNL M-989 Section 2.1.1.2, 1, Attachment 1.

3.5.3 Root pass and cover pass welds for the tank access panel shall be inspected for cracks using a dye penetrant test as required by the Acceptance Specification No. LBNL M-989 Section 2.1.1.3.

3.5.4 The Subcontractor shall notify LBNL of the pressure test date at least two weeks in advance to allow a representative of LBNL to witness the pressure test.

3.5.5 After the helium vessel passes the witnessed pressure test, the LBNL will provide a metal tag identifying the helium vessel as a LBNL tested pressure vessel. The tag shall be affixed to the outside surface of the vacuum vessel as specified in the top-level assembly drawings.

3.6 Bus Ducts:

3.6.1 The bus duct and lambda plate assemblies, MQX1 and MBX1 will be fabricated and tested at LBNL.

3.6.2 The ends of the bus duct will be capped to protect the power conductor and shipped to the Subcontractor along with the installation and handling instructions, LBNL-M994, Attachment 7.

3.6.3 The Subcontractor shall notify the LBNL of the installation date at least ten (10) working days in advance to allow a representative of LBNL to witness the bus duct installation.

3.7 Magnet Instrumentation Conduits:

3.7.1 The magnet instrumentation conduits, MQX2 and MBX2 will be fabricated and tested at LBNL.

3.7.2 The ends of the conduits will be capped to protect the wires and shipped to the Subcontractor along with the installation instructions, LBNL-M996, Attachment 8.

3.7.3 The Subcontractor shall notify LBNL of the installation date at least ten (10) working days in advance to allow a representative of LBNL to witness the conduit installation.

3.8 Beam Tube:

3.8.1 The beam tube and its cooling jacket will be fabricated and tested at LBNL.

3.8.2 The beam tube will be shipped to the Subcontractor with its ends capped.

3.8.3 The Subcontractor shall install the beam tube in the distribution box and make the final connection between the beam tube cooling jacket and the LD pipe in accordance with drawing numbers 25I206, 25I510 and 25I 252

3.8.4 Closeout weld in Section 3.8.3 shall be thermally shocked, pressure tested and vacuum leak tested per Acceptance Specification, LBNL-M989 Section 2.2, Attachment 1

3.9 Cryogenic Instrumentations:

3.9.1 Cryogenic instrumentations such as temperature sensors to determine the thermodynamic performance of the distribution box during operation will be supplied to the Subcontractor by the LBNL.

3.9.2 The Subcontractor shall install the sensor per installation procedures specified on the fabrication drawings.

3.10 Current Leads Installation and Conductor Splice Procedure:

3.10.1 The HTS leads along with their handling fixture will be delivered to the Subcontractor after they pass acceptance tests at FNAL.

3.10.2 Vapor cooled leads will be shipped directly from the vapor cooled lead manufacturer to the Subcontractor after they pass the acceptance test at the lead manufacturer.

3.10.3 The leads handling and installation instructions will be provided to the Subcontractor at the time of the lead delivery.

3.10.4 Current lead splice procedures shall be performed in accordance to Specifications No. LBNL-M982, M983 and M985, Attachment 9.

3.10.5 Subcontractor shall notify the LBNL at least ten (10) working days prior to starting the splice operation to allow for representatives from LBNL to witness the splice operation at the Subcontractor's facility.

3.10.6 Subcontractor shall provide a test sample of each type of splice to LBNL prior to performing the splice operation in the distribution box to demonstrate that the splice parameters are properly set.

3.11 Vacuum Vessel:

3.11.1 The vacuum vessel provides vacuum containment for internal components and supports the weight and dynamic loads inside the DFBX.

3.11.2 The positions of the internal components are directly coupled to the position and straightness of the vacuum vessel. Therefore, warpage of the vacuum vessel top plate during final weld operation in excess of the value stated in the Acceptance Specification LBNL M-989 Section 2.1.7 may cause the lead chimneys and the helium vessel to deviate from the tolerances specified in the fabrication drawings.

3.11.3 Weld rings where the chimneys are welded to the top plate maybe be utilized by the Subcontractor to reposition the chimneys

3.11.4 Subcontractor shall submit the vacuum vessel weld plan to LBNL for approval prior to fabrication. The plan shall include holding fixtures, welding equipment, weld time, number of passes, weld sequence, filler metal, shielding gas and cleaning procedures.

3.12 Part Cleaning, Identification and Storage:

3.12.1 Subcontractor shall submit their final cleaning procedures to LBNL for approval prior to fabrication

3.12.2 The inside of pipes shall be cleaned and capped prior to use in the fabrication.

3.12.3 Cutting fluids, metal chips, dye penetrant materials, and all other extraneous material shall be removed as components are fabricated.

3.12.4 MLI shall be protected during assembly. No fingerprints, oil or dust shall be allowed to remain on any surface of the MLI.

3.12.5 Only vacuum-compatible anti-seize compound shall be used on the assembly of components located in the vacuum space.

3.12.6 The Copper thermal shield shall be cleaned to a bright metal condition.

3.12.7 After parts or subassemblies are completed they should be bagged and properly stored to protect cleanliness and dimensional integrity.

3.12.8 Identification tags with drawing numbers shall be placed on parts without damaging or scratching the surface.

3.13 Welding, Weld inspection and Weld Repair

3.13.1 Subcontractor shall submit their welding procedures to LBNL for approval prior to fabrication.

3.13.2 The Subcontractor shall perform the work in accordance with the ASME Boiler and Pressure Vessel Code and the American Welding Society. However, the DFBX will not be "U" stamped.

3.13.3 All welds including temporary welds shall be performed by qualified and ASME certified welders. Welders' certifications to be submitted to LBNL prior to fabrication.

3.13.4 Distortion of welded parts shall be minimized and in accordance with the requirements stated in the Acceptance Specification LBNL M989, Section 2.1.7 in Attachment 1.

3.13.5 As stated in Section 3.5.3 of this Specification, all longitudinal welds in the helium tank except for the tank door welds must be radiographed. The radiographs and their interpretation must be included as part of the traveler as required by the Acceptance Specification No. LBNL M-989 Section 2.1.1.2, 1, Attachment 1.

3.13.6 Copper thermal shield joining shall be performed with Inert Gas Shielding or suitable fluxes such that the thermal conductivity or mechanical strength is unchanged from values specified in the material certifications.

3.13.7 The Subcontractor shall insure that weld metals are stored and used in accordance with applicable requirements of AWS D1.1. 4K Charpy Impact tests shall be carried out to qualify helium vessel base metal, welded metal, and weld procedure.

3.13.8 All welds shall be inspected by certified inspectors and in accordance with applicable requirements of AWS QC1. Subcontractor shall submit to LBNL weld inspectors' certifications for approval prior to fabrication.

3.13.9 All weld areas containing defects exceeding the standards of acceptance in AWS shall be repaired with applicable requirements of AWS D1.1.

3.14 Part Repair

3.14.1 Repairs to any GFM part of the DFBX during the fabrication or assembly process shall be pre-approved by LBNL.

3.14.2 Part repair that might involve welding, soldering, or brazing of any sort shall be pr-approved by LBNL.

3.14.3 Pipes shall not be bent to achieve position tolerances after completing the pipe vacuum leak test.

3.14.4 If repairs need to be done, the Subcontractor shall submit to LBNL a description of the problem and the location, the repair to be done, and the proposed methodology to be used for approval by LBNL.

4 Inspection and Acceptance Requirements

4.1 The Acceptance Specification LBNL-989, Attachment 1 defines the minimum required acceptance criteria, and outlines the essential dimensional checks and tests that must be performed on the cryogenic distribution boxes during fabrication and assembly.

4.2 The subcontractor must submit the following procedures for review and approval by LBNL prior to their implementation.

- 4.2.1 Mechanical measurement methods for the critical dimension checks listed in the LBNL-989
- 4.2.2 General vacuum leak check procedure
- 4.2.3 Specific pressure test procedures including flow schematics
- 4.2.4 General electrical continuity test method
- 4.2.5 General hipot test method

4.3 The DFBX assembly travelers must completely document all in process and acceptance tests so that LBNL and CERN have assurance that the appropriate measurements of tests have been satisfactory completed. The subcontractor is to maintain a separate traveler report for each DFBX.

4.4 The final acceptance of DFBX shall take place after conforming to all the acceptance tests specified in the Acceptance Specification LBNL-M989. Tests at CERN will be performed by LBNL staff or its designee.

4.5 Subcontractor shall provide any unique tools such as templates or manifolds manufactured specifically to perform DFBX acceptance tests which are needed to perform acceptance tests at CERN.

4.6 All dimensions and tolerances shown in the fabrication drawings apply at reference temperature of 20 C (68 F).

4.7 The LBNL representatives or designates shall have the option to perform inspections upon the parts and assemblies to validate certain dimensions or vacuum leaks rates.

5 Packing, Shipping and Handling Requirements

5.1 Packing and shipping shall be performed in accordance with Packing and Shipping Specification LBNL-M986, Attachment 2.

5.2 Each DFBX should be shipped with its test fixtures, any special lifting or handling fixtures and all design, fabrication and test documents.

6 Notification

- 6.1.1 In the event that the Subcontractor detects a mistake in the drawing, machining or fabrication of the parts listed herein, the Subcontractor shall notify LBNL within 24 hours. LBNL will have 72 hours, excluding weekends and official holidays, to respond to

such notification without incurring any costs due to idle equipment, manpower, or temporary storage space.

6.1.2 Subcontractor must notify LBNL at least 10 working days ahead of the dates the following activities will be performed:

- 6.1.2.1 Installation of the bus ducts MQX1 and MBX1
- 6.1.2.2 Installation of magnet power leads
- 6.1.2.3 Splicing of magnet cables
- 6.1.2.4 Helium vessel pressure test
- 6.1.2.5 Hi pot test in GHe of magnet conductor
- 6.1.2.6 Installation of the instrumentation conduits MQX2 and MBX2
- 6.1.2.7 Hi pot test in GHe of instrumentation conduits MQX2 and MBX2
- 6.1.2.8 Wrapping the helium vessel and lead chimneys with MLI
- 6.1.2.9 Welding of vacuum vessel plates
- 6.1.2.10 Final vacuum tests of all pipes and helium vessel after completing the vacuum vessel welds
- 6.1.2.11 Final dimensional checks of all pipes and flanges
- 6.1.2.12 Placing the DFBX in its shipping crate.
- 6.1.2.13 Shipping the DFBX to CERN.

7 Applicable Documents

7.1 The following documents and documents referenced therein form a part of this Technical Specification to the extent specified herein.

7.2 In the event of a conflict between the referenced documents and the contents of this specification the Subcontractor shall immediately notify the LBNL for clarification before completing the proposal or proceeding with work on the affected part.

7.3 No substitution or deviation from these drawing and specifications may be made without written authorization from the LBNL procurement representative.

- 7.3.1 Acceptance Specification LBNL-M989, Attachment 1
- 7.3.2 Crating and Shipping Specification LBNL-M986, Attachment 2
- 7.3.3 HTS Lead Splice Specification LBNL-M985, included in Attachment 9
- 7.3.4 120 Amp Vapor Cooled Lead Splice Specification LBNL-M983, included in Attachment 9
- 7.3.5 600 Amp Vapor Cooled Lead Splice Specification LBNL-M982, included in Attachment 9
- 7.3.6 MLI Application Specification LBNL-M990, Attachment 10
- 7.3.7 Cryogenic Distribution Box Flow Schematics, Attachment 6:
  - 7.3.7.1 The distribution boxes flow schematics for all 8 distribution boxes are provided in drawing numbers 25H408, 25H409, 25H410, 25H411, included in Attachment 6
  - 7.3.7.2 The flow Schematics specifies the DFBX cryogenic connections to the superconducting magnets and the CERN's cryogenic distribution system.
- 7.3.8 Drawing Package and Bill of Material
  - 7.3.8.1 Attachment 5 includes a set of size B engineering drawings fully describing requirements for the fabrication of DFBX-C and DFBX-G. Top-level assembly drawings for DFBX-A, DFBX-B, DFBX-E, DFBX-F DFBX-A, and DFBX-H are included in Attachment 6.
  - 7.3.8.2 The drawing package consists of top-level assembly drawings and part drawings.
  - 7.3.8.3 Bill of Material (BOM) for DFBX-C/G is included in Attachment 4,
  - 7.3.8.4 All references to LBNL design drawings listed in this specification refer to the latest revision of each of the drawings.

7.3.8.5 LBNL will revise drawings as a result of design changes. All revised drawing will be submitted to the Subcontractor prior to fabrication via engineering changes procedures. The Subcontractor shall be responsible for using the latest revision of the drawings.

7.3.8.6 For convenience, electronic files (CAD files) can be supplied by the LBNL in PDF, DXF or IGES format, but it is particularly emphasized that the supplied (paper) design drawings are the final authority as to the feature size, tolerance and locations. The LBNL is not responsible for the contents or use of the electronic files.

7.3.9 Electrical Wiring Diagrams, included in Attachment 6

7.3.10 Bus Ducts Installation Procedures, LBNL-M994, Attachment 7

7.3.11 Instrumentation Conduits Installation, LBNL-M996, Attachment 8

8 List of Government Furnished Material (GFM)

8.1 The LBNL will supply the Subcontractor with specific components needed for the distribution boxes final assembly. Specification No. LBNL-M995 in Attachment 3 includes the complete list of the GFM and their unit replacement cost.

8.2 The GFM will be made available to the Subcontractor at least two weeks prior to the agreed upon needed installation dates.

8.3 The GFM include the following components:

1. HTS current lead assemblies (drawing number 25I192)
2. Vapor cooled current leads assemblies (drawing numbers 24C322, 24C353 and 25I164):
3. Bus duct assemblies including busses, lambda plate and duct (drawing numbers 25M857 and 25M859)
4. Beam tube assemblies (drawing numbers 25I855, 25I510 and 25I252)
5. Interconnect bellows and welding flanges (drawing numbers 25I312 and 25I314)
6. Relief valve (25I911)
7. LHe diagnostic assembly (drawing 25I162)
8. CERNOX temperature sensors
9. Instrumentation conduits, MQX2 and MBX2 assemblies (drawing numbers 25I301, 25I251, 25I219, 25I249
10. Vacuum vessel enclosures, seals for D1 flange in DFBX-A, B, E and F (drawing numbers 24C351, 24C351, 24C394 and 24C395)
11. ISR jacks (drawing number 25I182) will be available at CERN

12. Taylor-Hobson tooling balls and surface plates (drawing numbers 25I868 and 25M820)
13. DFBX name plates and identification tags (drawing number 25M927)

9 Quality Assurance

9.1 General Requirements
Subcontractor shall prepare and implement a Quality Assurance (QA) program covering the procurement, fabrication, and testing and inspection of the subsystems. The subcontractor QA program shall be consistent with guidelines established in ANSI/ASQC C1-1996, General Requirements for Quality Assurance program. Subcontractor shall submit QA/Quality Control plan to LBNL for approval prior to the start of fabrication

9.2 Process Control, Inspection, and testing
Quality requirements for manufacturing functions and associated material handling and control, inspection and testing activities, and process equipment identification shall be planned, performed to written procedures and documented.

9.3 The Subcontractor shall submit the following specifications to LBNL for approval prior to fabrication:
- 9.3.1 Detailed fabrication and inspection plan
- 9.3.2 Vacuum leak checking procedures
- 9.3.3 Welding procedures
- 9.3.4 Cleaning procedures
- 9.3.5 Cold shock procedures
- 9.3.6 Any other non-destructive test methods that may be applicable to Subcontractor's Quality Control program.

9.4 Deviation and Nonconformance:
The QA Plan shall provide for disposition and resolution of departure from approved drawings, specifications, data, procedures, and standards. No work shall proceed on the proposed deviation until approved in writing by LBNL. Nonconformance and Deviation request forms are presented at the end of this Technical Specification documents.

9.5 Any planned deviation in the material, workmanship, dimensional tolerances, procedures, records, or qualification shall require written LBNL approval before proceeding. The Subcontractor shall insure proper description, documentation, and response in requesting a deviation. LBNL response time for action initiated by the subcontractor is as follows:
1. Routine: Seven days response required
2. Urgent: Three days response required
3. Emergency: 24 hours response required

9.6 LBNL reserves the right to have its technical or procurement representatives witness any or all manufacturing steps, tests and

inspections established under the Subcontractor's Quality Assurance program to demonstrate compliance with this Technical Specifications.

9.7 LBNL representative shall have visitation access to the Subcontractor's plant and personnel during normal operation hours with 24-hour notice for the purpose of conducting Quality Assurance and Audits.

9.8 Subcontractor shall provide a reasonable office space and office supplies for use by LBNL's representative during the visits to Subcontractor's plant.